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Hydraulic Structures for Wetlands

PURPOSE: This technical note examines hydraulic structures presently being used in wetland design. The examples given will provide insight to structure types being used in the field and how well they are succeeding.

BACKGROUND: The design and construction of a wetland site requires knowledge of the wetland type or functions that are to be achieved by the project. Examples of functional objectives include: waterfowl habitat including food and nesting sites, flood storage, water treatment to remove undesirable materials, sediment trapping, and ground water recharge. Also required is a knowledge of the operation, management and maintenance resources that will be available during the life of the project. Basic hydrologic data are required to determine the potential flows and water properties to which any hydraulic structures associated with the project will be subjected.

Hydraulic structures for wetlands generally fall into one of two categories: **water containing structures**, which are generally referred to as dikes, levees, or embankments, and **water control structures** of which there are a multitude of types and designs. In this technical note, dikes, levees, and embankments are collectively referred to as dikes.

DIKES: Dikes are structures constructed of earth or other suitable materials designed to contain water or protect lands against overflows from lakes, streams, and tides. Dikes, often a major component of wetland restoration, enhancement, or creation, can be effectively used in a wetland system to control flow paths and to minimize short-circuiting. Usual causes of dike failure are overtopping, undermining, sloughing, piping, or seepage along a water control structure placed through the dike. The design of the dike should eliminate these dangers as much as possible (USDA SCS 1992).

WATER CONTROL STRUCTURES: Water level and flow control structures are required if some control over the hydraulic regime and water budget of a particular wetland area is desired. The types of structures typically used in wetland design are consistent with water control devices used in general engineering practice.

Inflow is generally controlled by relatively simple structures, such as an open-ended culvert pipe, a vegetated spillway, or a channel. These structures should be sized to handle maximum design storm flows and to achieve the intended wetland function(s). Natural inflow can be supplemented by diversions, spring developments, or pump systems. The inflow structure must be designed to minimize channelization and short-circuiting by diffusing the inflow velocity.

The wetland function being obtained and the ultimate use and design of the wetland system control the outflow from a wetland. The wetland area may be designed for flood conveyance, which requires capacity to store and release storm runoff. Regulation pool elevation might be required to maintain proper water depth for specific habitat needs. The possibility of total drawdown of the wetland might be necessary for wetland management purposes.

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For impoundments with dikes 1 ft or less in settled heights, the Soil Conservation Service (SCS) recommends that vegetated spillways may be used in lieu of structures with dewatering obtained by cutting the dikes. For impoundments with dikes more than 1 ft in settled height, the types of structures which may be used include (USDA SCS 1992):

- A straight drop structure, which may be equipped with removable stoplogs constructed of treated timber, metal, sheet piling, rock, or concrete.
- A pipe provided with a swivel elbow and riser.
- A pipe drop inlet structure which may be equipped with a gate, valve, or plug for flow control.
- A pipe provided with a perforated riser.

Wetlands that are hydrologically isolated or that do not have a contributing drainage area will still require control structures to release the water that results from ground water inflow and precipitation.

EXPERIENCE WITH EXISTING STRUCTURES: In practice we have found a variety of structures in place. In general, they can be grouped as follows:

- Drop outlet structures.
- Spillways.
- Culvert pipes.
- Weirs.
- Level spreader inflow pipes.
- Pumping inflow with some type of diffuser.
- Dikes.

All of the above structure types have various designs. This list is not inclusive of all possible structures. The following paragraphs illustrate the diversity of structure types and applications for wetland projects. Detailed information for each example can be obtained from the indicated references.

Drop outlet structures are commonly used in wetland mitigation projects. The SCS in Jackson, WY, provided documentation of an open-type water control structure for use where public access is limited, and an innovative locking type structure for accessible areas (Figure 1). This structure is shown here because of its unique design and capabilities. The wetland function in both areas is year around waterfowl habitat (Personal Communication, 1992, J. Kremer, District State Conservation Engineer, Jackson, WY). The Lyndon Q. Skidmore Wetlands at Harry S. Truman Reservoir, MO, were created by constructing a 3,500-linear-ft levee. Two low-cost water-level control structures using PVC stoplogs were installed. The function of the project is to provide natural foods and sanctuary conditions for migrating waterfowl, shorebirds, and other wildlife (Briuer 1991). The Shop Creek Stormwater Quality Enhancement Project in Aurora, CO, has an outlet structure from the permanent pool pond to the channel and five bowl-shaped, soil-cement drop structures along the channel. Water quality,

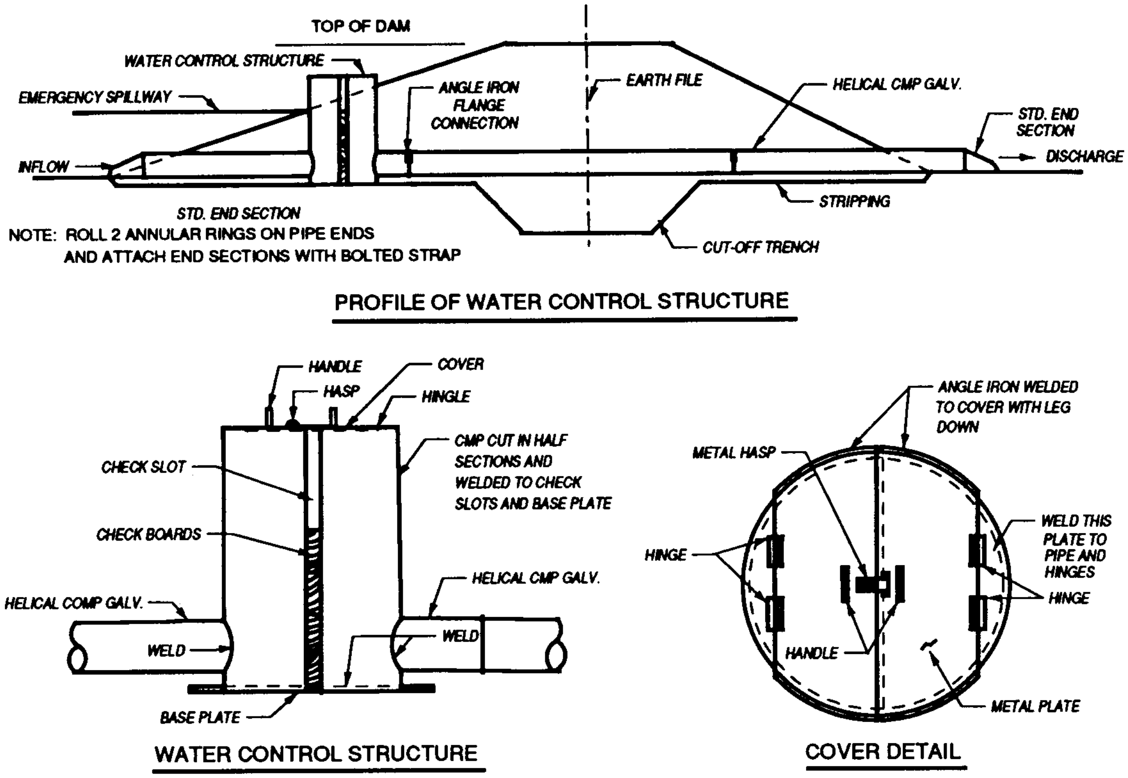

Figure 1 Schematic of a locking type control structure used in accessible areas

sediment control and habitat were design goals of this project (Muller Engineering Company, Inc., et al. 1988).

Spillways have been used in Tennessee Valley Authority's (TVA) constructed wetlands for treating acid drainage. The Fabius Coal Mines acid drainage wetlands system employs spillways for conveying both inflow from the existing pond and outflow into the natural wetlands (Watson and Hobson 1989). In an urban detention pond-wetland system in Orlando, FL, an overflow spillway is used between the detention pond and the wetlands (Martin 1988).

Culvert pipes exist in the Bolsa Chica Wetlands in CA. Three inflow culvert pipes transport water from outer Bolsa Bay into the wetland area. Wetland enhancement is in the future for this muted tidal wetland (Personal Communication, April 1992, L.Z. Hales Research Engineer, USAE Waterways Experiment Station, Vicksburg, MS).

Weirs are used in a variety of projects for controlling wetland outflow. The Des Plains River Wetlands Demonstration Project, a midwestern riparian wetland, utilizes outflow weirs with parshall flumes for flow measurements (Personal Communication, May 1992, D. Manson, Wetlands Research, Inc., Chicago, IL). The design wetland functions include water quality, flood control and habitat (Wetland Research, Inc. 1990). The urban detention pond-wetland system in Orlando also employs a weir built around a drop inlet for discharge from the wetlands (Martin 1988). Everglades National Park in Florida has four gated weirs that regulate the flow into the park (Gunderson 1986).

Level Spreader inflow pipes are used in constructed wetlands for wastewater treatment. TVA has used level spreader inflow pipes in their work in the design of small community wastewater projects (Watson and Hobson 1989).

Pumps are often used to supply inflow to a wetland area. In the Des Plains River project, inflow pumps, located in the river, pump water through a pipe that terminates in a concrete cylindrical riser pipe that disperses the water and allows for gentle flow into the wetlands (Manson 1992). In two study sites in NC, agricultural waste was pumped into wetlands for natural treatment. The structures included inflow pumps and a diffuser canal to distribute the water laterally before entering the wetland buffer area (Chescheir and Skaggs 1991).

Dikes are used effectively in wetland systems to control flow paths and minimize short-circuiting. TVA uses finger dikes to create a serpentine configuration in the Kingston Steam Plant. Divider dikes are used to separate cells and attain desired length-to-width ratios at constructed wetlands in Benton, KY (Watson and Hobson 1989).

STRUCTURAL FAILURES: Reasons for wetland mitigation failures are varied. Examples of structural failures, that is structures that have been in place and have been the cause of the wetland function not being attained, have been difficult to find. Because successes are usually published, information on unsuccessful designs and problems is more difficult to locate. Often a preference of one type of structure over another can be found. It is not a "failure" of the structure but an engineering preference due to ease of construction, operation, or cost.

The TVA has extensive experience with constructed wetlands to treat both acid drainage from coal mining operations and wastewater for small communities. A water control box with an elbow and a rotating standpipe is the TVA's preferred outlet structure for constructed wetlands. TVA has tried other designs, such as weirs with movable plates but found them to be more difficult to operate and construct compared to the simplicity of the control structure with the swiveling standpipe (Personal Communication, April 1992, J.T. Watson, Water Quality Branch, TVA, Chattanooga, TN).

On the Snake River at Jackson, WY, near the airport north of town, a headgate was constructed without regard to the hydrology of the river. The headgate, presently 3 ft in the dry, had to be replaced to get water into the wetland. The wetlands function is year-round habitat (Myers, Miller, and Tate 1992).

A 2-year study documenting the hydrology of two wetland buffer areas in the Albemarle-Pamlico Peninsula of eastern NC consisted of three main components, the drained agricultural area, the pumping station, and the wetland buffer area. The pumping stations had three pumps each, allowing for a wide range of pumping rates. One site had a diffuser canal to distribute the water laterally before entering the wetland buffer area. The other site did not have a diffuser canal during the first year, resulting in uneven water distribution and reduced effectiveness of the wetland buffer area. A diffuser canal was constructed to correct the problem demonstrating the need to discharge the inflow into the wetland areas using either sheet flow, or some other type of diffuser mechanism, to reduce velocities and to minimize channelization (Chescheir and Skaggs 1991).

Coyote Hills Regional Park located on San Francisco Bay contains enhanced wetlands that have dikes with many large control valves that were installed to allow the water level to be controlled in the various cells. Muskrats have tunneled extensively through the dikes eliminating the capability to vary the water levels. At other locations, beavers have constructed their own water control structures resulting in water levels differing from the original design.

Coastal wetlands surrounding San Francisco Bay have been enhanced by breaching existing levees to allow the tidal flow to enter the previously isolated area. Additional channels were constructed through these areas to allow the flow to reach the remote sections of the wetland.

SUMMARY: Several factors affect the selection and design of hydraulic structures. Considerations include:

- Flow control may be modified by animal or human activities where local populations may attempt to change the level of the water within the project.

- Floating debris may affect the flow conveyance if allowed to collect on or in the structure. The structure may need to pass inflowing sediment or be designed to hold sediment.

- Structural materials should be chosen to be consistent with the project life.

  Steel pipe is subject to corrosion and chemical attack.
  Concrete may be abraded and is also subject to chemical attack.
  PVC is subject to abrasion and ultraviolet light.
  Vegetated structures may be reinforced with geotextiles or gabions.
  Riprap is a traditional material for small flow structures.

  Safety and aesthetics should always be considered in choosing the type of structure.

- Straight drop structures are not appropriate for areas were water sport activities may occur due to the plunging and roller flow conditions at such structures. Strong roller action or hydraulic jumps should be avoided at locations where water sport activities occur.

CONCLUSION: Failures to achieve the desired wetland type and/or function can primarily be attributed to design error rather than structural selection. Wetland restoration, creation, and enhancement are relatively new areas in engineering and design criteria are still in the development stage. Research indicates the design should be as simple as possible.

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